Representing Labials and Velars: a Single ‘Dark’ Element*

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ABSTRACT. Segmental structure is traditionally represented using distinctive features which describe articulatory properties such as tongue position and glottal state. Yet evidence from language acquisition and some phonological processes suggests that language users associate segments primarily with their acoustic attributes, not with articulation. In Element Theory, features (elements) map on to those acoustic properties which participate in segmental contrasts and dynamic processes. An Element-based approach is able to capture important phonological generalisations that cannot be expressed using articulatory features, such as the close association between labials and velars. These are linked in acoustic terms by a similar ‘dark’ spectral pattern and in representational terms by the same ‘dark’ element.

Keywords: Element Theory, place of articulation, dark resonance, speech perception, spectral patterns

1. Overview

This paper begins by challenging the established view that segmental structure is represented using distinctive features. It argues that traditional features do not adequately describe what language users know about the sound system of their native language. Moreover, it claims that this inadequacy is largely due to the articulatory, speaker-oriented nature of the features themselves. It then reviews evidence in support of an alternative view that features should be neutral between speaker and listener. Using the Element Theory approach (Harris and Lindsey (1995, 2000)) as a model, it demonstrates how elements — that is, features based on linguistic properties of the speech signal — are able to account for some important phonological generalisations that cannot be handled straightforwardly by referring to articulation. One such generalisation is the inherent link between labials and velars which, it is proposed, share the acoustic property of ‘dark’ resonance. The dark quality of labials and velars is formalised as a falling pattern which is common to the spectral profiles of these two categories.

2. The Status of Articulatory Features

Since the time of SPE (Chomsky and Halle (1968)), segmental structure has been described using distinctive features; indeed, it is the very endurance of traditional features which places them at the core of mainstream phonology. They provide a rich and powerful vocabulary for describing speech sounds cross-linguistically, and for this reason their status and their role in phonological analysis is rarely questioned.

Most features have their origins in speech production. Of course such features do refer to phonological categories, but nevertheless their labels indicate a close association with articulation: for example, [±back] refers to tongue position, [±anterior] to place of articulation, [±nasal] to airflow, and so on. Yet although most features reflect the properties of articulation, there is little support for the notion that segments should be represented with a bias towards the speaker. The ongoing preference for speaker-oriented features seems to be based not so much on positive evidence as on an underlying assumption — in our view, a highly questionable assumption — that phonology should ultimately encode pronunciation. Let us consider the main arguments against
the prevailing articulation-based view of features, and at the same time, assess the validity of an alternative acoustic approach to segmental description.

Because of their bias towards articulation, we can expect articulatory features to succeed in modelling the knowledge that speakers have about their native phonology. But it is not obvious how the same features relate to listeners’ knowledge. For example, how do listeners recover linguistic information from the input speech signal? This process must engage the phonological grammar, yet according to the established feature-based view, phonology is concerned primarily with speech production, not perception. In the literature, several suggestions have been made to account for listeners’ perceptual ability. According to the Motor Theory view (Liberman and Mattingly (1985)), for example, listeners perceive the acoustic input and then convert it into the articulatory movements that would be needed for (re)producing the same string as an output utterance. Yet this seems implausible, given that in the first stages of acquisition we find a strong tendency for speech perception to develop earlier than speech production. Evidently, infants make no attempt to perform this acoustic-to-articulatory conversion.

On the basis of early language, then, it is apparent that speech perception exists independently of speech production. We shall assume a fairly uncontroversial model of acquisition in which infants begin to acquire language by first perceiving adult input forms. Then, on the basis of this input they build mental representations which serve as the beginning of their native lexicon; and only later do they go on to reproduce these stored forms as spoken language. But while speech perception is a necessary stage on the acquisition path, speech production is not; this is confirmed by the ability of mutes and those with abnormalities of the vocal apparatus to acquire a native grammar. By contrast, for those who are profoundly deaf, speech production never develops to a native-like level. This is presumably because these language users fail to perceive any acoustic input from the speech signal, and as a result, cannot build native phonological representations.

So the evidence from acquisition places speech perception in a more fundamental role than speech production. But in fact this reflects an earlier view which prevailed up until the time of SPE. Prior to SPE’s publication there was a clear tendency to see perception as being more basic than production. This position is evident in the work of Sapir, who saw perception as having a primary role in language learning and language use whilst viewing the ability to produce spoken language as only secondary. And a similar position was later taken up in Jakobson and Halle (1956), which proposed a feature set based on properties of speech perception: for example, the features \[\text{strident}/\text{mellow}\] and \[\text{compact}/\text{diffuse}\] are defined in acoustic terms. However, the perceptual tradition was brought to a sudden halt by the publication of SPE, whose authors introduced — without clear motivation, it should be pointed out — a comprehensive switch to articulatory features. It is this articulation-based approach that has survived, largely unchallenged, in most present-day theories of segmental structure.

But besides being at odds with the acquisition facts, speaker-oriented features are incompatible with some recent developments in phonological theory such as Feature Economy (Clements (2005)). According to feature economy, languages are expected to show a preference
for economical features — that is, for features which participate in a large number of contrasts; the more economical a feature is, the higher its status as an established grammatical property and as a legitimate member of the universal feature set. But in reality, some very common features actually turn out to be uneconomical, since they account for just a small number of contrasts. And here we suggest that this mismatch can be traced back to the articulatory nature of these features. Take the feature [±lateral], for instance. Although lateral consonants are present in the sound systems of many languages, there is little real evidence for ‘lateral’ as an independent phonological property; it is rarely active in processes, for example. In other words lateral airflow, as an articulatory property, appears to be relatively unimportant from a grammatical point of view. Instead, if we take a more theory-neutral standpoint we may understand ‘lateral’ simply as the phonetic result of producing a sonorant stop which is oral as opposed to nasal (e.g. [l] versus [n]). By focusing on articulation, traditional features run the risk of elevating some aspects of speech production to the status of phonological units; and the presence of these units — motivated by articulation rather than by phonology — will inevitably lead to an overly powerful grammar which can predict phonological events that fail to be observed.

As the preceding paragraphs have shown, the validity of articulation-based features cannot be taken for granted, especially if they are accepted on non-linguistic grounds such as theoretical tradition or descriptive adequacy. Indeed, if generative phonology is to maintain its original goal of modelling the knowledge of an ideal speaker-hearer, then features should preferably be formulated without bias towards either the speaker (Browman and Goldstein (1992)) or the listener (Jakobson and Halle (1956)). Below we follow Harris and Lindsey (2000) in attempting to model the linguistic knowledge common to both speakers and listeners. This means associating phonological structure with the speech signal, as this is the only aspect of the communication process which involves both parties: speakers use their vocal organs to create acoustic patterns in the signal, while listeners perceive those same patterns and decode them into meaningful language.

We will attempt to show how a model of representation based on properties of the speech signal can counter the problematic aspects of traditional speaker-oriented features discussed above. In addition, this approach has the advantage of being able to capture some significant cross-linguistic phonological patterns which are left unaccounted for under an articulatory approach. In the next section we focus on one such pattern, namely, the inherent link between labials and velars. This will be followed by an outline of the way speech signal properties may be formalised in the grammar in terms of element structure.

3. The Phonology of Labials and Velars

3.1. Introduction

In terms of articulation, there are clear differences separating nasal stops such as [n ɳ] from voiced obstruents such as [d ɡ]. And this is reflected in their traditional feature specifications, which do not reveal any close similarity between these categories. On this basis there seems little reason for treating them as a natural grouping. Yet there is now an increasing awareness that nasals and voiced obstruents do have much in common phonologically, as
confirmed by their participation in alternation and lenition patterns (Nasukawa (2005)). The same can be said of the association between back vowels and rounded vowels. In many vowel systems these two categories pattern together, although this fact cannot be captured directly using traditional features, which are based on the articulatory properties of tongue position and lip attitude. To encode this relation in the grammar we must make appeal to some external rule or markedness statement.

Labials and velars provide another case where there is undeniably a phonological relation between the two categories, and where a traditional description based on speech production fails to capture this in a natural way. With labials specified as [+ant −high] and velars as [−ant +high], they appear to have little in common in terms of articulation. Yet we find plenty of evidence to link them phonologically. We review this evidence below, before going on to develop an account of their representational similarities.

3.2. The Labial-Velar Connection

A historical connection between labial and velar (but notably, not alveolar) consonants is revealed by the study of cognates in Germanic languages, as shown in (1):

(1) labial~velar sound correspondence

\[
\begin{align*}
\text{laugh} &\quad [\text{laf}] \ (\text{English}) \sim \ lachen \ [\text{lax\text{\_}n}] \ ‘\text{laugh’ (German)} \quad (\text{PIE *klak-}) \\
\text{Luft} &\quad [\text{luft}] \ ‘\text{air’ (German)} \sim \ lucht \ [\text{luxt}] \ ‘\text{air’ (Dutch)} \quad (\text{PGmc *luftuz-})
\end{align*}
\]

The PIE verb stem *klak- ‘laugh’ contains a final velar, which is retained as the spirant [x] in modern German but which has been reinterpreted during the development of English as a labial [f]. Meanwhile the labial fricative [f] in Proto-Germanic *luftuz- ‘air’ is reinterpreted as the corresponding velar [x] in the modern Dutch form lucht [luxt]. Looking beyond the Germanic group, we also find historical sound changes involving labials and velars in Bantu languages (e.g. *kumu ‘chief’ (Proto-Bantu) ~ pfuma (West Teke)) and Romance languages (e.g. lingua ‘tongue’ (Latin) ~ limbă (Romanian)).

Further evidence for a link between labials and velars comes from dialect variation in Swedish (Engstrand et al. (1998)). Alongside the standard dialect form tvättas ‘be washed’ we find the variant kvättas in the Lappfjärd dialect, where coronal [t] is interpreted as velar [k] in the context of a following labial [v]. In terms of articulation-based features there is no obvious phonological motivation for this variation; but if it is assumed, as we shall argue below, that labials and velars are represented by the same segmental property (namely, the element [U]), it becomes possible to treat [tv]~[kv] as a case of [U]-assimilation.

Another assimilation process operates in Finnish (Durand (1990:49)), where the velar fricative [y] is interpreted as its labial counterpart [v] when it occurs between high rounded vowels ([u] or [y]). Again distinctive features fail to capture the naturalness of this process, whereas an explanation based on acoustically grounded elements treats the [y]~[v] effect as an assimilation involving vowel and consonant. In Element Theory a high rounded vowel is represented by a headed [U] element in a nucleus, the same headed [U] representing consonant labiality in non-nuclear positions (for element headedness, see below). Flanked by vowels
containing headed |U|, [γ] adopts the headed |U| characteristics of its surrounding context and interprets these as the labial resonance in [v]. Interestingly, velars (represented by non-headed |U|) are targeted by headed-|U| assimilation while other consonant types (represented by other elements) are not. Evidently, substituting non-headed |U| (velar) for its headed equivalent (labial) is grammatical whereas the seemingly arbitrary replacement of one element by another is not observed.

The natural affinity between labials and velars is also apparent from the distribution of secondary articulations. Many languages exploit labial as a secondary articulation, but interestingly, labialization tends to target velars rather than coronals: for example, [gʷ] is far more common than [dʷ]. The strength of this preference becomes clear when we consider figures from the UPSID database, which records 60 languages with labialized velars but only 2 languages with labialized coronals. This, together with the historical evidence shown above, provides strong support for the assumption that labials and velars have phonological (but non-articulatory) properties in common. This is presumably what motivated Jakobson and Halle (1956) to posit the feature [grave] in velars and labials, where [grave] indicates a concentration of acoustic energy at the lower end of the spectrum. In the following section we focus on Element Theory, and show how the acoustic properties common to labials and velars are reflected in a common representational property, the ‘dark’ element |U|.

3.3. Representing Labials and Velars

In Element Theory, segmental structure is constructed from a small number of basic units called elements, each of which is single-valued and can appear either alone or in combination with other elements. Elements map on to spectral patterns in the speech signal (Nasukawa and Backley (2008)) — in particular, on to those patterns which carry linguistic information about the identity of segments (and, by extension, of morphemes). Importantly, these patterns are not to be confused with raw acoustic properties such as formant frequency or voice onset time. Instead, it is assumed that humans instinctively seek out linguistic cues in the speech signal whilst ignoring any non-linguistic information. And it is these linguistic cues that are represented by elements in phonological structure.

The spectral properties of a velar stop burst (followed by a vowel) take the shape of a falling pattern, as shown in (2a) below. We propose that this falling pattern is an identifying characteristic of velar resonance.

(2) a. Velar [k]    b. Labial [p]
But a comparison with the falling spectral pattern in (2b), which shows the transition from a labial stop to a following vowel, reveals a remarkable similarity between the two. So, labial resonance is identified by the presence of a falling spectral pattern too. Of course the labial and velar patterns are not identical, because these two categories are distinguishable. Nevertheless they do share the same basic falling shape, which, we shall claim, gives labials and velars their similar so-called ‘dark’ auditory qualities. In this way, language users associate dark resonance with an energy peak at the lower end of the spectrum, which is interpreted as either labial or velar.

Given that a direct mapping exists between an element and its associated spectral pattern, it follows that two phonological categories identified by the same basic pattern must be represented by the same element. As already indicated, we propose that the |Ul| element is present in the structure of both labials and velars. The fact that these properties contrast, however, means that they are nevertheless distinguished by some structural difference. We propose that this difference is one of headedness. Element Theory allows elements in the same segmental expression to combine in unequal proportions, thereby creating an internal head-dependency relation (Backley and Nasukawa (2007)). In the representation of a segment, one element acts as the head of the compound expression; this status renders the head element phonologically stronger and acoustically more prominent than its dependent(s). Of course, using asymmetric head-dependency relations in linguistic structure is nothing new; the concept is central to other frameworks such as Dependency Phonology (Anderson and Ewen (1987)). The use of headedness has the advantage of bringing segmental structure into line with the description of other aspects of linguistic structure such as prosody, where the importance of head-dependent asymmetry has been recognized for some time.

Given that labials have darker acoustic properties than velars, we claim that they are represented by headed |Ul|, the stronger form of the dark element (conventionally, headed elements are underlined). By contrast, the lesser degree of dark resonance in velars indicates that these sounds are represented by non-headed |Ul|. Now, this difference in headedness ought to be reflected in the spectral patterns of these two categories, since element structure is mapped directly on to these linguistic patterns in the acoustic signal; and predictably, we do find a subtle difference in the spectral shape of each segment type. The patterns in (2) indicate that the term ‘dark’ refers to a low frequency spectral peak, but they also show that the lower the frequency of the peak is, the darker the acoustic characteristics are. In the case of labials, the falling pattern in (2b) begins at a relatively low frequency (i.e. near the ‘zero’ point on the frequency axis), which gives the fall a long duration and a relatively shallow gradient. This long or exaggerated fall is consistent with the claim that labials are associated with a prominent (or headed) |Ul|. By contrast, in velar sounds the energy peak occurs at a higher frequency, as shown in (2a). This results in a fall with a shorter and less exaggerated duration; we propose that listeners interpret this as the presence of |Ul| in its less salient (or non-headed) form.

In this way, the acoustic signal indicates not only the presence of an element but also its relative salience — that is, its presence as either a head or a dependent. And in the case of the
element |U|, Element Theory succeeds in capturing both the relatedness and the distinctiveness of the labial and velar categories.

3.4. Beyond Labials and Velars

On the assumption that labials and velars are represented by the same element, it is natural to question whether this is a unique situation, or whether there may be other segment types which are also distinguished only by the headedness properties of the same element. In fact, recent work within Element Theory provides strong evidence in favour of a similar analysis for the element |N|; in Nasukawa (2005) it is argued that this element is present in the representation of voiced obstruents as well as nasals, the two categories being similarly distinguished by headship. Again this leads to the desirable result of formalizing the strong association between two classes which, in articulatory terms, seem to have little in common.

If this analysis were to be extended further, then another potential candidate is the special phonological relation between alveolars and palatals: while velars and labials share a characteristic dark quality, alveolars and palatals seem to have a light quality in common:

| (3) | a. Alveolar [t] | b. Palatal [c] |

The spectral profiles in (3) reveal an obvious similarity between alveolars and palatals, each producing a rising pattern (as opposed to the falling pattern associated with dark resonance). Does this suggest the need to recognize a single element — a ‘light’ element — to represent both? This is an interesting question, and one which we intend to pursue in the future.

4. Conclusion

We have discussed reasons for questioning the use of traditional articulatory features, noting that an inherent problem of the articulation-based approach is its failure to capture some important generalisations such as the phonological link between labials and velars. But by severing the ties between phonology and articulation, and adopting representations based on speech signal properties instead, it is possible to account for these generalisations in a non-arbitrary way. The Element Theory model shows how such an approach can be implemented, as it bases phonological relations on acoustic similarity. We have focused on one particular element, the ‘dark’ element |U|, which unites labials and velars as a natural group by virtue of the falling
spectral pattern common to both. In the future we will extend this line of argument to other seemingly related properties such as alveolars and palatals.

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Note

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References